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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

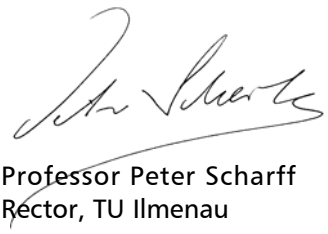
- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.



Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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A groundwater model for the area Darkhan in Kharaa river basin

Introduction

Water, especially drinking water, is a valuable substance worldwide. And also worldwide we are faced with the problem of decreasing drinking water resources. In the BMBF project “Integrated Water Resources Management for Central Asia: Model Region Mongolia (MoMo)” this serious problem is taken account. Based on the interaction of surface water, ground water and water distribution systems, influenced by climatic change, an integrated approach dealing with special problems of each system has been established. The project considers the Kharaa river basin in Mongolia, an arid region with typical problems like decreasing water resources and drinking water quality.

In this project the research at Technical University of Ilmenau is responsible for developing optimal strategies for the groundwater extraction in the area Darkhan in the Kharaa river basin. A simulation model is to be developed as a base for the optimization. The first step of our research is to develop an adequate mathematical model of the groundwater system and all required model parameters will be determined according to the data from the local area. This model will be used to calculate the current amount of groundwater, to forecast the future capacity and to develop strategies for an optimal, sustainable water extraction.

Model Area

The model area is located in the Kharaa river basin, Mongolia, close to the town Darkhan, the third largest town of Mongolia with around 70,000 inhabitants. Because of only a few surface water resources available drinking water is extracted from ground water. The area is characterised by an arid, continental climate with a yearly precipitation between 300 and 400 mm. Only a small amount of the precipitation contributes to ground water recharge. Most of it is lost by run-off or evaporation.

Consequently, the main recharge of ground water is done by the river Kharaa, with a length of 300 km and a catchment area of around 15,000 km². In the determined model area, as shown in Figure 1, the river has a width between 10 and 20 m and is fanning out. The water level highly depends on the precipitation. Thus the level is high in spring and low in summer and autumn. In winter the river is frozen, partly up to the ground because of the low temperature. This phenomenon has also to be taken into account.

The flow of ground water mainly occurs in a band along the river which determines the ground water system. The width is around 20 km. This unconfined aquifer consists of porous media which is characterised by alluvial sand and gravel with interlaced sandy loam [4], [5]. The depth of the water transporting layer is between 65 and 70 m dividing up in different layers. The level of ground water is dependent on the season, in average around 3 m below the ground.

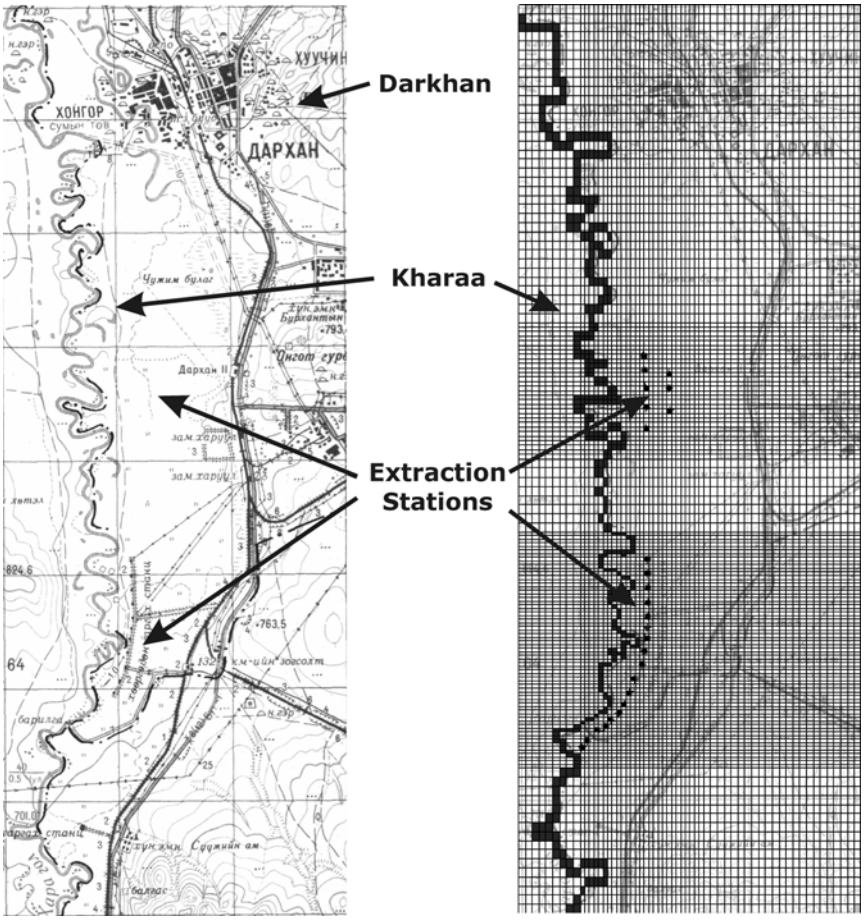

Figure 1 - Overview of the model area Darkhan

As mentioned above, ground water is used for drinking water purpose because of low

surface water resources. There are two main extraction systems with 18 and 8 wells. These systems are between 250 and 700 m far away from the Kharaa River. Each well has a depth of around 60 m and a capacity of 160 m³ per day. The water is extracted from a depth of 30 m below ground. Based on this analysis of the region a mathematical model will be developed.

Modelling

In a porous medium like this type of aquifer the ground water flow could be described by the following partial differential equation (1). This equation is a combination between the Darcy's equation which describes the velocity of water in porous media and the continuity equation which describes the mass balance of water [2], [1].

$$\frac{\partial}{\partial x}\left(k_x \frac{\partial h}{dx}\right)+\frac{\partial}{\partial y}\left(k_y \frac{\partial h}{dy}\right)+\frac{\partial}{\partial z}\left(k_z \frac{\partial h}{dz}\right)=S_0 \frac{\partial h}{\partial t}+q(x,y,z,t) \qquad (1)$$

The level of ground water is described by the variable h which can be obtained at the solution of this equation. The parameter k represents the conductivity of the porous medium, individual for each of the three directions of space. The parameter S_0 represents the specific yield of the aquifer. The water extraction of the aquifer is described by the parameter q.

Because the project is in the beginning phase and gaining data from the local area is very difficult, now we have only a few data available. In this case we have to make some assumptions. The first assumption commonly used in modelling such processes is that the aquifer is treated as isotropic and homogeneous. Second, a typical conductivity for alluvial sand combined with gravel [2] can be chosen. Third, the horizontal conductivity is equal in each direction and the vertical conductivity is chosen ten times smaller because usually vertical flow is slower. For the parameter S_0 the same assumption is made and thus one value is used for the whole model. As a next step the model layers are to be defined. To better reflect the effect of ground water flow we use 3 layers with same parameters. We assume that the recharge only occurs in the first model layer.

To solve the partial differential equation (1) boundary conditions are necessary. We assume the head from the river as a constant one, and a no-flow boundary condition to the neighboured aquifer, which has only a little recharge to the aquifer. Due to

cutting the aquifer we define an inflow and outflow to the neighbour aquifer in north and south. As extraction parameters the two extraction sites are modelled by pumps with a depth of 70 m with an extraction of 160 m³ per hour for each well.
A grid is defined based on a topographical map of the model area. We build up the grid which is refined near the river and extraction stations.

Calibration and Simulation

After the parameterisation discussed above, the model calibration can be made. Here parameters are changed to fit best to the measured results using the method of least squares. Based on this result, a first model with the assumptions can be achieved. A detailed model will be developed step by step if new data are available.
One of the first steps was therefore the installation of data loggers which measure the level of ground water. The measured level can be used to calibrate the model. Based on this measurement data we also can determine more model parameter, e.g. through pumping tests. Acquiring data and improving groundwater simulation model are important tasks in the near future.
For modelling and simulation we use the software Visual MODFLOW [3]. It uses the technique of finite differences to solve the partial differential equations. The most advantage of MODFLOW is the open source. Also the input and output files can be accessed by other software tools. Thus the simulation model created with MODFLOW can be coupled to other software, e.g. optimisation software.
A steady-state simulation for the model area describing monthly water balance is being made. The next step will be the simulation based on a transient model which represents the real ground water flow. The results of steady-state as well as transient simulation will be presented.

Conclusions

After a short introduction to the project and related facts the model area Darkhan was explained. The model area considered was described in detail. The concept of modelling is explained by making some assumptions because only a few data is available. Thus only a rough simulation model of the area Darkhan in Kharaa river basin is presented and simulation results will be presented.
Based on these results the model will be developed further and will become more detailed, so that it can be used for doing forecasts. Based on this detailed model of

the groundwater system, an interface to optimisation software for gaining optimal strategies for the water extraction will be established. This will allow analysing the potential of optimising the groundwater capacity and of the investigation of the water resource management in the area considered.

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Authors:

Dipl.-Ing. Stefan Röll
Dr.-Ing. Siegbert Hopfgarten
Prof. Dr.-Ing. habil. Pu Li
Technische Universität Ilmenau,

Fakultät für Informatik und Automatisierung
Institut für Automatisierungs- und Systemtechnik
Fachgebiet Simulation und Optimale Prozesse
Postfach 10 05 65
98684 Ilmenau, Germany
Phone: +49 3677 69-2869, -1418, -1423
Fax: +49 3677 69-1415
E-mail: {Stefan.Roell,Siegbert.Hopfgarten,Pu.Li}@TU-Ilmenau.de